THE CULTURE OF THE IMAGINATION IN THE STUDY OF SCIENCE.

It is with a great deal of humiliation, and really with reluctance, that I come before this audience after the addresses to which you have just listened. I should be sorry to have you think of science, or the scientific man, as well represented by the picture of the man with the muck-rake in the Interpreter's House in Pilgrim's Progress. You have had the imagination pictured before you as an angel of light, and have heard the rustle of her wings. You have seen her as a great goddess, walking with flowing robes over Olympus, or Parnassus, or I know not just what mountain. I want to speak of imagination; but my heroine, I am sorry to say, does not appear either with wings or in flowing robes. She is what we call, in the present day, a "work lady," and she is dressed in homespun, and she is useful even more, perhaps, than she is ornamental. I have been trying, ever since I heard the opening phrases of the first speaker, to reach up my poor muck-rake and pull down a golden crown to put upon her head, but I have not been able to do it, and so I must introduce her to you, as she is, a plain helper in everyday work.

"Imagination," says Wundt, "is thought by means of images." The material or food for thought must have been already stored up for us somewhere in the mind, is represented to us by memory aided by association, and to these old percepts imagination gives a new form or grouping.

We perceive objects, we think about their relations. When we recollect an object, a man for example, we very likely find that certain parts, features, or characteristics are far more clearly represented by memory than others. You ask me if I remember A. After a little thought I answer: "he was the little man with the big nose, was he not?" When A's nose has once emerged in my memory, other features and traits follow rapidly until finally I have a fairly accurate picture of his physical, mental, and moral structure. Thus far there has been memory and association, but very little, if any, true imagination.

But we have seen that even in memory objects tend to become dissociated, broken up, and to emerge piecemeal, so to speak. But we always tend to dissociate objects by fixing our attention, first on one part then on another. As A sat in the class room his nose may have attracted my attention earlier and more frequently than any other feature. These dissociated fragments or parts are the material with which imagination works.

Imagination combines these *disjecta membra* furnished by memory, association, and dissociation or analysis, and produces an image entirely new to me, which may, or may not, correspond to any existing objective reality. It has not merely *re*produced, *re*presented; it is productive, constructive, in a sense, creative.

When we think about an object we are tracing its real or possible relations, trying to place it in its proper setting in regard to a host of other objects. And the relations or setting of an object can be viewed from almost innumerable different standpoints with widely different results.

Finally, imagination is *pictorial* thought. But the mind can form an image of objects never perceived by the eye. I can imagine a pain, choral music, or even a taste or an odor; in a word, anything which is presented by the senses. I cannot imagine abstract truth. For abstraction has removed many of the details on which the picture of the imagination depends for its vividness.

The work of the imagination is, therefore, to relate or combine by means of mental images objects, or parts of objects, perceived by the senses and represented by the memory aided by association. Our question is, to what extent does science cultivate or require such a function ?

We notice that natural science deals with objects perceived by the senses. Furthermore, the first task of the scientist is to analyze his material into its parts or elements. The biologist dissects, the chemist analyzes, the physicist traces molecular structure or forces. All three busy themselves with the relations of these parts, elements, or forces, and recombine them in new

and different relations. And the relations and combinations of these material objects and the working of their forces are eminently adapted to pictorial representation. We can hardly imagine a mental power better suited for the material and modes of scientific investigation. Does the scientist use it, or ought he to do so?

Stanley is sailing northward on an unexplored river. He thinks he is on a branch of the Nile. The river broadens and sweeps westward, and Stanley sees himself crossing nearly the whole breadth of the African continent and coming out at the mouth of the Congo into the Atlantic Ocean. To recognize thus early his position in a vast, unexplored wilderness, was even more a feat of the imagination than of judgment.

When I studied geography I learned to bound all the states and territories. I committed to memory the names of all capitals, principal towns, rivers, mountain ranges, and chief products. When a river or mountain chain reached the boundary of the state, it disappeared, to reappear at a later date as if by magic, and sometimes under a new name, in some neighboring state or territory. If you had asked me how to go from Boston to Chicago, I could not have told you; for, while I had been studying Illinois, then one of the western states, the middle states had all sunk in oblivion and left only a blank. I was like the New York militia: I could not be moved out of the state where I belonged. Now, every child in kindergarten has journeyed in his imagination all over the world. He has visited the capitals, climbed the mountains, sailed the rivers, explored the fields, mines, and forests. He likes geography, and will not forget it. Best of all, it is of some use to him.

Every invention is as much a work of the imagination as of ingenuity. Everybody had seen, though very few had noticed, that children's shoes wore out first at the toes. One man put to himself the famous question solved by the deacon in building his one-horse shay: How can I make that part wear as long as the rest? And he solved it by imagining various caps on the toes of the shoes. I do not mean to say that he communed with

himself in words, saying: Go to now, let us imagine various substances on the toe of that shoe. He used his imagination as unpremeditatedly as a shoemaker picks up an awl. He finally selected copper as the suitable substance. And the copper-toed shoe brought a fortune to the inventor and made everybody wonder that he had not thought of it himself. And what is true of the copper toe of the shoe applies equally well, though in a far higher degree, to Watt's steam engine, the Jacquard loom, and to every machine. The model must exist and work in the imagination of the inventor before it can be even drawn on paper.

The geologist investigates a world never seen by human eye. He sees it a molten globe, then covered with an almost unbroken and shoreless primeval ocean. He sees continents emerge, and grow, and take their definite shape. He tells us of great mountain chains rising and then wearing away under the denuding power of water and ice. The palæontologist peoples this globe with a succession of strange plants and animals, and tells you of their structure and relations and modes of life. Take away imagination, and what has become of your palæontologist and geologist?

Turn to physics. You have all, I suppose, read Mr. Tyndall's lecture on the "Use and Limit of Imagination in Science." You remember how he begins by describing the waves produced by a pebble falling into smooth water. From these he proceeds to waves of sound and light, to the subjects of reflection and refraction, and explains the blueness of the sky by motes invisible even under the highest powers of the microscope. He does not describe; he paints. It is a panorama, rather than a lecture. You *see* the ether waves reflected or bent as clearly as you have ever seen an ocean wave break on a stony beach.

Perhaps zoölogy may seem to afford less opportunity for the use of the imagination. Let us see: The student is studying a very prosaic grasshopper. He observes its external form and structure and then dissects it. He studies it until he can see in his imagination a transparent model of the whole animal, and can

describe the relative position of all its parts as seen from above, below, or in section. Then, perhaps, he studies its physiology He sees the nerve wave proceeding to the nerve center, and thence along a motor nerve to start the microscopic engines in the muscles. He watches the dissolving of food in the intestine, observes it passing out into the blood to be caught by the whirlpools of the individual cells. He sees the waste come whirling out again to be cast out of the body. And yet not one of these processes is visible to the eye of sense. If he will attempt to discover what is going on in the cell, he can begin to understand the processes only when he has pictured all the changes in his imagination. When we question him about any structure or process, we ask him not: "Do you know or understand?" but, "Can't you see?"

But the student wishes to know the anatomy of a fly or spider, and perhaps he has no time to dissect these. He reads a description of them, notices wherein they differ from the grasshopper, modifies in these respects the model already formed in his mind, and thus gains a picture or model of these forms also. He makes a thorough study of but comparatively few forms, and then mentally constructs a very fair representation of all other animals as soon as he has heard them described or seen pictures of them.

He wishes to learn how the grasshopper develops from the egg. He studies sections of the successive stages under the microscope or the illustrations of monographs. The imagination combines these into representations of the successive stages and of the changes from one to another.

Suppose that the zoölogist had to memorize descriptions of all these forms and stages, how much of such wordy stuff would the memory retain? But the mind affords an indefinite wall-space for pictures. It never wearies of them or allows their essential features to become blurred or indistinct.

When we notice what a store of pictures the mind carries with it, and the strength of its tendency to think in images rather than in words, we cannot help seeking some explanation

of so striking a fact. We have all noticed the great power and ceaseless play of the imagination in young children. I cannot resist the temptation to hazard the query whether this habit of pictorial thought is not an inheritance from our old brute ancestors, who had to think in images because they had not yet attained the power of articulate speech. Certain facts, at least, seem to me to strongly favor such a conjecture. But here we have no time to follow or enlarge upon it.

Our student has been using his imagination, but only as a means of learning and retaining a wide range of mere dry facts of anatomy, physiology, and embryology. But if he stops here he is a mere drudge, a collector of facts, whose meaning and relations are hidden from him. He is still dealing with particulars. He has made no generalizations, arrived at no laws, caught sight of no development. He has a clear vision of most valuable food for thought, but he has not yet begun to digest it and really think.

As Professor Hardy has said, "To see is not enough, to explain is everything. The discovery of a germ is important; but vastly more so is its unknown relation to that other fact, the diseased organism. And until observation can answer we imagine." The investigator begins by picturing in his mind all possible relations between the germ and its host. The image of a poison secreted by the germ occurs among others. The pictures and conjectures with which he has thus far been groping into the unknown can hardly be reduced to the form of conscious reasoning. Soon the image of a poison, a ptomaine, secreted by the germ gains in distinctness and plausibility. He must imagine and then test its working. But only after the conjecture is clearly pictured before the mind can there be real judgment and generalization. First comes the conjecture pictured by the imagination, then logic and reasoning, then the test by observation and experiment.

This is the necessary order of discovery, and it is the best order for the student who will follow in the footsteps of the discoverer. It is, and must be, the path of the discoverer. His

mind must work pictorially. When we work merely with words and descriptions, the mind very quickly wearies. It is slow, dull, dry, hard, work; and we labor against an ever increasing friction and resistance. We plod along, taking up one detail after another; or gain a general concept only to find it barren and repulsive. Then the imagination comes to our relief. The picture rises before us in all its fullness of concrete detail, reality, and life. We begin to feel interested. The interest dispels our weariness, rouses up our flagging will, and we work with enthusiasm. The picture, unlike the dead abstraction, lives and works. The forces or influences which radiate from, or beat upon it, tempt us to calculate their results. At first the pictures shift before our minds as rapidly as in a kaleidoscope. But gradually those features which best conform to all our past experience and observation begin to persist and compel the details to group themselves around them. When the picture has gained a certain degree of completeness and stability, it gives us a working hypothesis which we can put into words. And the clearness of our expression of the working hypothesis will be proportional to the clearness, accuracy, and vividness of the picture furnished by the imagination.

But the vividness of pictorial thought has another great advantage. Whether or not we accept the theory of physiology that the stronger stimulus of certain cells in our brain causes stronger outgoing currents which pour not only along old courses but into a multitude of new channels — however we may explain it, there is little doubt that a vivid impression awakens the mind to new relations hitherto unperceived. And the discovery of a new relation may revolutionize all our modes of thinking. The newly discovered relation of the falling apple to the moon led Newton to the discovery of the law of gravitation. And when Archimedes saw in the water of the bath not his body but the king's crown, he ran naked and shouting through the streets of Syracuse. The picture of imagination may be like the flash of lightning which at once illumines all that was before shrouded in darkness.

And the student, if wisely taught, follows the path of the discoverer. First he conjectures, then thinks, and finally tests. And the chief use of the laboratory method is that it enables him to follow this course. When it has degenerated into mere cutting and slicing, and drawing, it has lost its chief value.

But have we not been faithfully warned that the imagination has no place in science? "The more imagination," we are told, "the less reality." We expect of the scientist sober thought, not brilliantly presented guesses. Such views have always found able defenders and should be treated with respect. Hypotheses spring up like mushrooms, and last about as long. The imaginative student is set to study a starch-grain under the microscope, and he makes out of the starch-grain almost anything of which he can find a picture in his text-book. At the barest suggestion from teacher or companion he cries with Polonius: "By the Mass, and 'tis like a camel, indeed;" or: "It is backed like a weasel," and finally it becomes "very like a whale." "All this," you say, "comes from using the imagination."

We must start with guesses, conjectures, hypotheses; though we need not publish them before we have tested them. Without imagination you can have no Darwins, Huxleys, or Tyndalls; no palæontology or geology. When the student calls the starch-grain an amœba, we do not tell him beware of imagination; we bid him look again and draw what he sees. What the scientist needs is not less imagination but more careful and accurate observation, more patient reasoning, more rigid tests of his hypotheses.

But the successful scientist will always exercise his own imagination and that of his pupils. He will not allow "this valuable gift of nature to be repressed by a bookish and wordy education." He will encourage no day-dreaming fancy. He will demand that the pictures of the imagination shall be rigidly tested to see that they correspond to some objective reality. But within these limits and with these restrictions, the student of science will cultivate his imagination as faithfully as the stu-

dent of art. And he will train and control it with a far more scrupulous fidelity.

The subject was further discussed in an informal manner by President Timothy Dwight, of Yale University.

At the close of the discussion, invitations were extended to the members of the association and their guests to visit Mt. Holyoke College at South Hadley during their stay in the vicinity of Springfield, and also to visit the Art Museum of Springfield.

The association then adjourned until evening.

FRIDAY EVENING

The association reassembled at 7:45 and listened with great interest to Professor William M. Sloane, of Columbia University, upon the subject:

HOW TO BRING OUT THE ETHICAL VALUE OF HISTORY

THE ethical value of history! Argument by title is a common form of fallacy and this apparently simple phrase contains an admission which would suffice to call forth the vigorous remonstrances of many thinkers. Some who have but recently passed away and some who are still living, a numerous band of ardent investigators, deny or have denied that the cosmic process is ethical, that there is any other value in the study of history than the discovery of truth, which is sufficient unto itself and must not be profaned by relegating it to a place in a chain of causation. Yet the trend of general thought is, for the moment at least, toward a different philosophic system, a system which makes this topic of ours important and even vital. By one of the inexplicable but frequent antinomies of the human mind there is to be observed a remarkable movement of that liberal thought which rejects the supernatural, to accept a well-developed form of Theism as the basis of belief and of conduct. The rigidity of the cosmic process is denied. Novelty, progress, the ideal are emphasized. The laws of nature are regarded as fixed